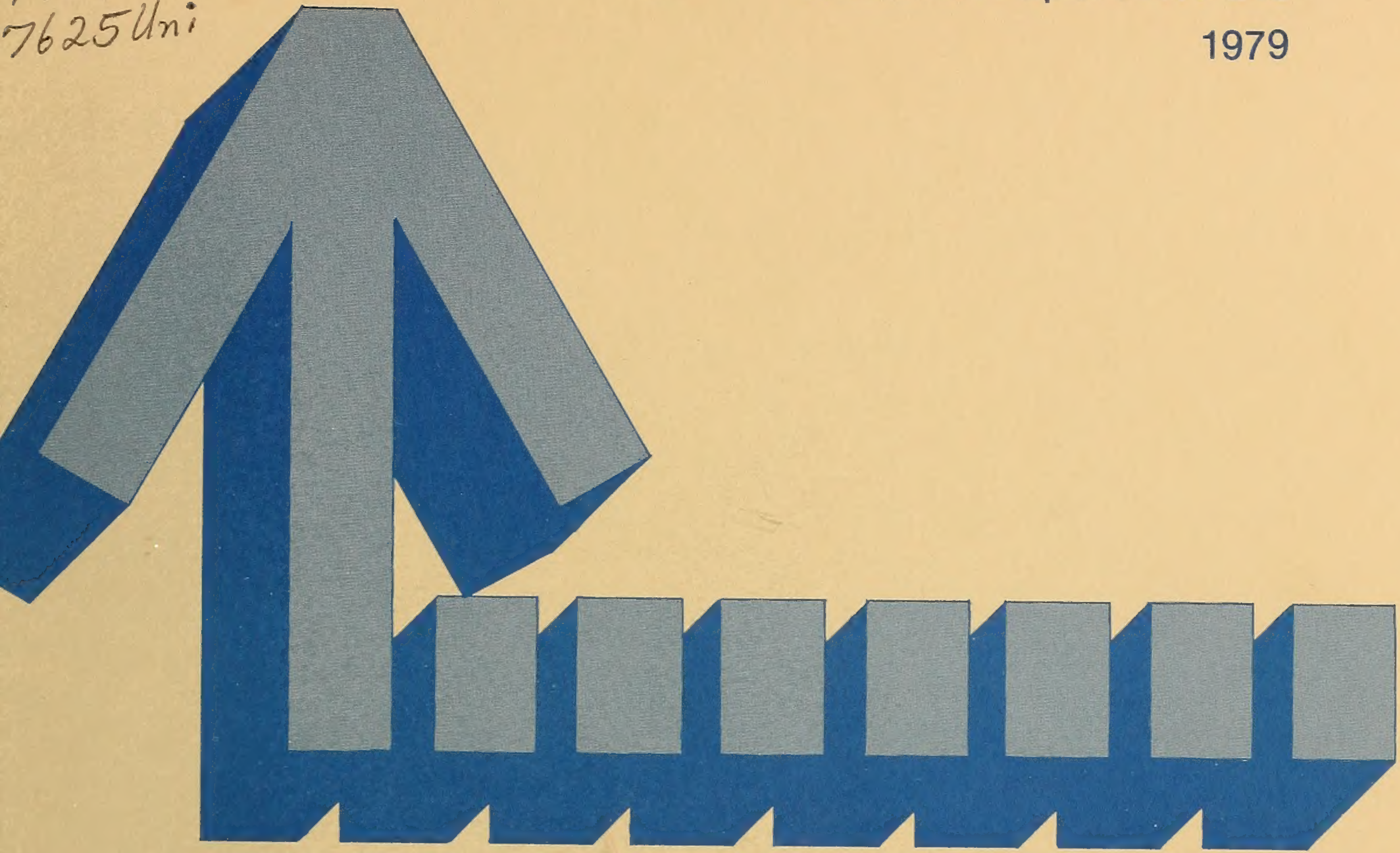
Research Paper PNW-248
1979



Regeneration in MIXED CONIFER CLEARCUTS in the Cascade Range and the Blue Mountains of Eastern Oregon

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Metric Conversion

1 foot = 0.3048 m
1 inch = 2.54 cm
1 acre = 0.4047 ha
1 tree per acre = 2.47 trees per hectare

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REGENERATION IN MIXED CONIFER CLEARCUTS IN THE CASCADE RANGE AND BLUE MOUNTAINS OF EASTERN OREGON

Reference Abstract

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1979. Regeneration in mixed conifer clearcuts in the Cascade Range and Blue Mountains of eastern Oregon. USDA For. Serv. Res. Pap. PNW-248, 24 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A survey of clearcuts in mixed conifer forests of the Cascade Range and Blue Mountains of eastern Oregon showed that, on the average, clearcuts were adequately reforested with a mixture of advance, natural, and planted reproduction. Planted ponderosa pine dominated clearcuts at elevations of less than 5,300 feet; and at higher elevations in the Cascades, considerable amounts of true fir and mountain hemlock advance reproduction were present. Seedling establishment was better on more northerly aspects while increasing amounts of grass had a negative effect on stocking.

KEYWORDS: Regeneration (stand), regeneration (natural), regeneration (artificial), mixed stands, Oregon (Cascade Range), Oregon (Blue Mountains), silvicultural systems (clearcutting).

RESEARCH SUMMARY

Research Paper PNW-248
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A regeneration survey of clearcuts in mixed conifer forest in the Cascade Range and Blue Mountains of eastern Oregon was made to obtain an overview of reforestation status and to identify key environmental factors influencing regeneration establishment. Plots were randomly located in clearcuts harvested during the 1953-1973 period in the mountain hemlock/grouse huckleberry and mixed conifer/snowbrush-chinkapin communities in the Cascades and in the grand fir/big huckleberry community in the Blue Mountains.

On the average, clearcuts were well stocked with a mixture of advance, natural, and planted reproduction of a number of species. At elevations below 5,300 feet, planted ponderosa pine was the dominant species because of its good survival and fast growth. Considerable amounts of vigorous true fir and mountain hemlock advance reproduction were present in some of the higher elevation Cascade plots. Natural regeneration was generally present in adequate numbers, but distribution was sometimes patchy, and it was often in a subordinate position beneath trees or woody vegetation.

Greater stocking was generally associated with more northerly aspects and less stocking with increasing amounts of grass. Other factors such as age, slope, and forbs had a positive or negative effect on stocking depending upon the species and community.

Planting ponderosa pine in clearcuts below 5,300 feet where vigorous advance reproduction is lacking has resulted in fast growing, well stocked stands and is the preferred reforestation method. At higher elevations, lodgepole pine is a desirable species to plant because of its greater resistance to snow damage. Planting stock should be used that was grown from seed collected in the same geographical and elevational zone as the clearcut. If sufficient numbers of vigorous advance reproduction exist to form the new stand, careful logging and slash disposal methods to save these trees will eliminate the problems associated with natural or artificial regeneration. Natural regeneration after clearcutting is an uncertain reforestation method because so many factors involved are beyond the forester's control. It is, therefore, most useful as a means of supplementing existing advance or planted reproduction.

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Introduction

Mixed conifer forests on the east side of the Oregon Cascade Range and in the Blue Mountains of northeastern Oregon contain a variety of species growing in diverse environments. During the 1950's and early 1960's, clearcutting was the primary method of harvesting timber in these forests. More recently, the shelterwood system has been used to increase the probability of obtaining natural regeneration by moderating harsh microclimates found on many high elevation sites or improving the esthetic quality of harvest cuttings.

Success of regeneration on these clearcuts has been mixed, ranging from poor to good in various locations, but there has been no broadscale attempt to evaluate the regeneration or to relate it to environmental factors. Clearcuts in eastern Oregon mixed conifer forests are now old enough for regeneration to be established. Therefore, in 1976, I began a survey of regeneration on these clearcuts and a study of the factors affecting its establishment. This paper reports the results of the field survey conducted during 1976 and 1977 on the Deschutes, Winema, Umatilla, and Wallowa-Whitman National Forests.

Objectives

The purpose of this study was twofold: (1) to quantify regeneration found on the clearcuts and (2) to identify environmental factors associated with the presence or absence of regeneration.

Specific study objectives were:

1. To determine success of regeneration in terms of stocking percentage and density (number per acre);

2. To determine species composition of regeneration;

3. To determine origin of regeneration as preharvest (advance) or postharvest (natural and planted); and

4. To determine the relationship between regeneration and some measurable environmental factors such as elevation, aspect, slope, and time since harvest.

Study Areas

Stand structure and species composition of mixed conifer forests in eastern Oregon are extremely variable, depending upon site, logging history, insect and disease attacks, and wildfire. Within the broad, general area classified as mixed conifer forests, a number of forest zones are recognized based on the single species which is the major climax dominant. These forest zones are described by Franklin and Dyrness (1973). Major tree species found in these zones are ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta* Dougl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.), Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.), Pacific silver fir (*Abies amabilis* (Dougl.) Forbes), western white pine (*Pinus monticola* Dougl.), western larch (*Larix occidentalis* Nutt.), Engelmann spruce (*Picea engelmannii* Parry ex. Engelm.), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.).

EASTERN CASCADES

A number of plant communities have been identified within mixed conifer forests on the east side of the Oregon Cascades by Volland (1976). Identification was based on the dominant overstory tree along with the dominant understory shrub, forb, or grass. Study areas (plots) were located in two of these plant communities: (1) a high elevation mountain hemlock/grouse huckleberry community and (2) a lower elevation mixed conifer/snowbrush-chinkapin community (table 1). Understory vegetation in the mountain hemlock/grouse huckleberry community is generally sparse, consisting primarily of grouse huckleberry (*Vaccinium scoparium*), Prince's pine (*Chimaphila umbellata*), and pinemat manzanita (*Arctostaphylos nevadensis*). Major

Table 1--Mean and range of some characteristics of clearcut areas sampled in Cascade and Blue Mountain plant communities of eastern Oregon

Characteristic	Cascades				Blue Mountains	
	Mt. hemlock/ grouse huckleberry		Mixed conifer/ snowbrush-chinkapin		Grand fir/big huckleberry	
	Mean	Range	Mean	Range	Mean	Range
No. of plots	28	--	15	--	50	--
Clearcut size (acres)	29	10-80	24	10-50	31	10-120
Elevation (feet)	5,980	5,200-6,800	4,780	4,100-5,900	4,737	3,800-6,300
Slope (percent)	11.8	0-40	7.1	0-22	9.7	0-40
Age (years)	14.3	3-19	12.9	4-16	16.3	10-22
Seedbed (percent coverage)[1/]						
Mineral soil	25.5	2-60	27.3	5-75	10.3	0-40
Litter	19.9	5-40	31.5	2-50	45.9	13-75
Slash	22.1	11-45	16.1	6-26	18.5	10-30
Litter & slash	20.8	3-45	21.4	2-43	19.3	5-40
Understory vegetation (percent coverage)						
Forbs	1.1	0-20	2.5	0-13	41.5	0-66
Woody	17.4	0-58	18.8	0-40	22.5	0-62
Grass & sedge	11.5	0-35	17.4	0-50	22.2	0-56

[1/] Total of all seed bed categories do not add to 100 percent because of small areas of some quadrats occupied by rocks and stumps.

understory vegetation in the mixed conifer/snowbrush-chinkapin community consists of snowbrush (*Ceanothus velutinus*), golden chinkapin (*Castanopsis chrysophylla*), pinemat manzanita, dogbane (*Apocynum pumilum*), and fireweed (*Epilobium angustifolium*).

Study areas are within the pumice plateau region of south-central Oregon (fig. 1). Soils in this region are immature Regosols (Vitrandepts) developed from aerially deposited dacite and rhyolitic pumice ejected from Mount Mazama (Crater Lake) about 6,500 years ago. These well-drained, coarse-textured soils have thin A horizons low in fertility which grade into unweathered sand and gravel. A finer textured buried soil is found at a depth of 2 to 6 feet (Larsen 1976).

BLUE MOUNTAINS

Plant communities of the Blue Mountains of eastern Oregon have been described by Hall (1973). All of the clearcuts examined in this study were located in the grand fir/big huckleberry community in the Umatilla and Wallowa-Whitman National Forests (fig. 1). Understory vegetation in mixed conifer forests of the Blue Mountains is much more diverse than in the Cascade Range, especially the forb component which averaged 41.5-percent cover compared to only 1.1 percent in the Cascade mountain hemlock forest (table 1). Principal understory species are big huckleberry (*Vaccinium membranaceum*), heartleaf arnica (*Arnica cordifolia*), sideflower mitrewort (*Mitella stauropetala*), piper anemone (*Anemone piperi*), yarrow (*Achillea millefolium*), strawberry (*Fragaria virginiana*), prickly currant (*Ribes lacustre*),

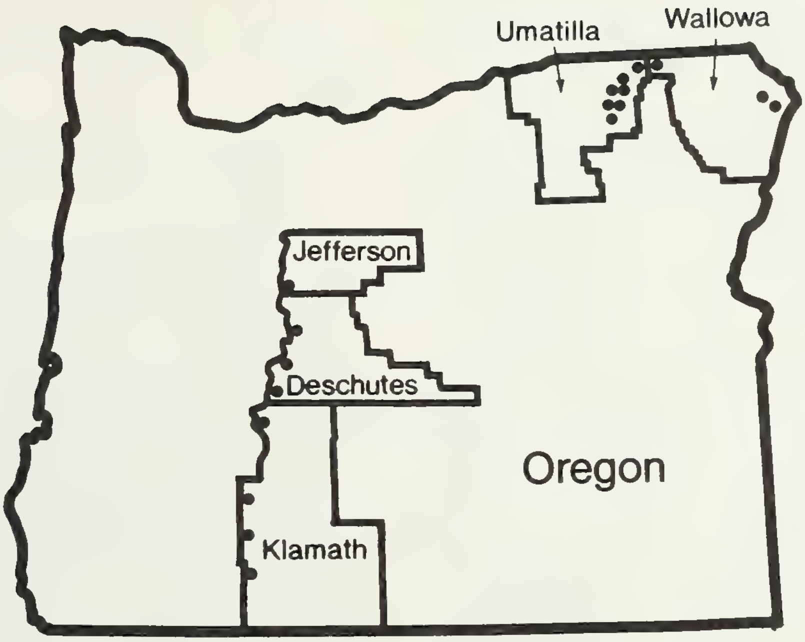


Figure 1.--Study area locations in Oregon. Four to seven plots were sampled in the vicinity of each dot.

baldhip rose (*Rosa gymnocarpa*), and dwarf blackberry (*Rubus lasiococcus*).

Predominant soils of the grand fir/big huckleberry community are the Regosols (Vitrandepts) developed in the ash layer deposited from Mount Mazama or Glacier Peak. These are well-drained soils with silt loam A-C horizons over older buried soils or basalt (Wade 1975).

Methods

SURVEY DESIGN AND PLOT SELECTION

Clearcut areas within the east-side Oregon Cascades and the Blue Mountain region were considered as separate populations. A record of areas clearcut between 1953 and 1973 in the mixed conifer forest was obtained from the U.S. Forest Service Regional Office in Portland, Oregon. In this study, the sampling unit was a square plot 10 acres in size. Therefore, all clearcuts 10 acres or larger were considered as candidate areas for sampling. The total number of 10-acre units in the clearcuts in each geographic region was then determined (fractional portions of 10-acre areas were not included).

In each geographic region 50 samples (plots) were then selected at random from the total number in that region. In most cases, this resulted in only one sample per clearcut; but several of the larger clearcuts were sampled with two or more plots. Within each clearcut, sample plot or plots were located in the same manner as sections are numbered in a township, beginning at the northeast part of the clearcut.

Candidate sample plots were rejected if they contained three or more living seed trees per acre, if the area was seeded with tree species, or if it had been converted to nonforest uses. When a plot was rejected, it was replaced by another from a random list of alternate plots. Because of time limitations, only 43 plots were sampled in the Cascade Range.

Some clearcuts were stocked with varying amounts of advance reproduction.

It is more accurate to refer to the harvesting method in these units as an overstory removal or the final cut in a shelterwood system rather than a clearcut. For the purpose of this study, however, units were considered clearcuts if all of the mature overstory was cut.

DATA COLLECTION

A grid of 25 sample point locations (subplots) was centrally located on each 10-acre plot. Circular subplots were systematically spaced at 1-chain intervals on five parallel lines 1 chain apart containing five subplots each. At each of 25 sample point locations in the plot, two concentric subplots (1- and 4-milacre) were examined for regeneration and associated environmental variables. Individual sample points were rejected if conditions such as streambeds, marshs, swamps, active roads, gravel, cinder pits, solid rock, or erosion occurred on more than one-half of the subplot thus making it unsuitable for regeneration. (Only 0.3 percent of the subplots were rejected for these reasons.)

Information about the clearcut unit and the timber stand in which it was located was obtained from Ranger District records and from field observations. Information obtained was the plant community in which the plot was located, average elevation, timber type, date of harvest, slash treatment method and year of treatment, species planted and year of planting, subsequent cultural treatments, and general notes on regeneration size, growth, distribution, or damage. The plant community was identified by observing adjacent uncut stands.

On each 1-milacre subplot the total number of trees of each species was counted and recorded by class (origin). Regeneration was classified as being of preharvest (advance) origin or of postharvest (subsequent) origin. Trees of subsequent origin were further subdivided into 1- and 2-year-old seedlings from natural seedfall, seedlings 3 years and older from natural seedfall, and planted trees. On each 4-milacre subplot, the species and origin (advance, natural subsequent, or planted) of the tree most likely to dominate the subplot because of its size and vigor was recorded.

Identification of planted trees was accomplished by using information on species planted, date of planting, and spacing. In clearcuts where plantation survival was high, regular rows of planted trees were clearly visible. Planted tree identification was less certain when survival was low, but counting whorls to check tree age helped to determine the planted trees.

On each 1-milacre subplot, the following environmental factors were observed and recorded:[1/] aspect, slope, seed bed condition (mineral soil, litter, slash), degree of burn, understory vegetation (forbs, woody, grass), distance from subplot to timber edge, and presence or absence of animal damage.

DATA ANALYSIS

To illustrate the present degree of reforestation, data were summarized in a number of tables showing tree numbers and stocking percentage by species and origin for the plant communities. To determine the relationship between regeneration and environmental variables, stepwise multiple regression procedures were used to fit linear equations of the form $Y = b_o + b_1X_1 + b_2X_2 + \ldots.b_nX_n$ to the data. Dependent (Y) variables used were stocking percentage of the various species and origins, and independent (X) variables were the environmental factors given in the appendix.

[1/] See appendix for details of procedures for measuring and coding the environmental factors.

Results and Discussion

EASTERN CASCADES

Regeneration Stocking and Density

Regeneration on clearcuts in both the mountain hemlock/grouse huckleberry and the mixed conifer/snowbrush-chinkapin communities was adequate in terms of all species established before and after logging. An average of 53 percent of the milacre subplots were stocked in 28 plots in hemlock type compared with 59 percent in mixed conifer community (table 2). If total stocking is evaluated on the basis of 4-milacre quadrats, 80 percent of the subplots were stocked in the hemlock clearcuts and 92 percent in the mixed conifer.

Relative importance of advance reproduction and planted stock in the two plant communities can be seen in table 2. In the hemlock clearcuts, advance reproduction was the second largest component of the regeneration (509 stems per acre), while in the mixed conifer clearcuts, it was smallest (43 stems per acre). On the other hand, planted trees were a major component of regeneration in mixed conifer clearcuts, but only a minor part of the total in hemlock type. The differences in abundance of advance reproduction can be explained by the lack of slash treatment on 14 of the plots in the hemlock type.

Table 2--Average stocking percentage and number per acre, with standard errors, of all species on clearcuts in the east-side Oregon Cascades, by class of reproduction and plant community (based on 1-milacre quadrats)

Class of reproduction	Plant community					
	Mt. hemlock/grouse huckleberry			Mixed conifer/snowbrush-chinkapin		
	No. plots	Mean ± S.E.	Range	No. plots	Mean ± S.E.	Range
			Stocking percent			
Advance	28	18.2±4.1	0-72	15	3.1±1.3	0-16
Subsequent						
1 & 2 years	28	16.9±3.9	0-72	15	23.2±4.7	4-64
3 years and older	28	27.4±4.4	0-72	15	19.7±4.0	0-68
Planted	18	14.0±2.8	0-40	14	37.4±3.6	16-60
All classes except 1 & 2 years	28	45.4±4.1	4-96	15	48.3±3.6	28-72
All classes	28	53.0±4.9	4-96	15	58.7±3.1	36-80
			Number per acre			
Advance	28	509±147	0-3200	15	43±18.1	0-200
Subsequent						
1 & 2 years	28	386±133	0-3160	15	491±141	80-2000
3 years and older	28	593±119	0-2080	15	333±71	0-840
Planted	18	149±29	0-400	14	431±45	160-720
All classes except 1 & 2 years	28	1203±229	40-5120	15	779±93	280-1200
All classes	28	1589±263	80-5440	15	1269±156	480-2640

Because slash was undisturbed, more advance reproduction remained in these clearcuts than in the mixed conifer clearcuts where all the slash was treated (generally piled and burned). The poorer stocking of planted trees on the mountain hemlock clearcuts can be attributed in part to reduced survival of planted ponderosa pine at the higher elevations.

A considerable number of 1- and 2-year-old seedlings were present on clearcuts in both plant communities. In fact, this class of reproduction comprised the single largest category (491 per acre) in the mixed conifer clearcuts (table 2). The role of these seedlings in the total regeneration picture, however, is not as great as their numbers might suggest. Many of these young seedlings will die. And, it was noted that most of these seedlings were found growing in suppressed positions under woody vegetation or beneath larger planted or advance reproduction. The primary effect of these young seedlings was to increase the density of the regeneration rather than to greatly raise stocking levels. In the mountain hemlock clearcuts, for example, stocking was increased on 50 percent of the plots, but on only 3 of the 28 plots was the gain more than 12 percent. In the mixed conifer clearcuts, stocking was raised on 80 percent of the plots, but on only 4 of 15 was the gain more than 12 percent.

As expected, a highly significant exponential relationship was found between total number of trees per acre and percentage of stocked milacres (fig. 2). This is the same general type of relationship reported in other studies of natural regeneraton (Bever 1949, Harris 1967, Lynch and Schumacher 1941, Wellner 1940). This relationship shows that there are always more trees per acre than the number indicated by the minimum level curve which shows the theoretical

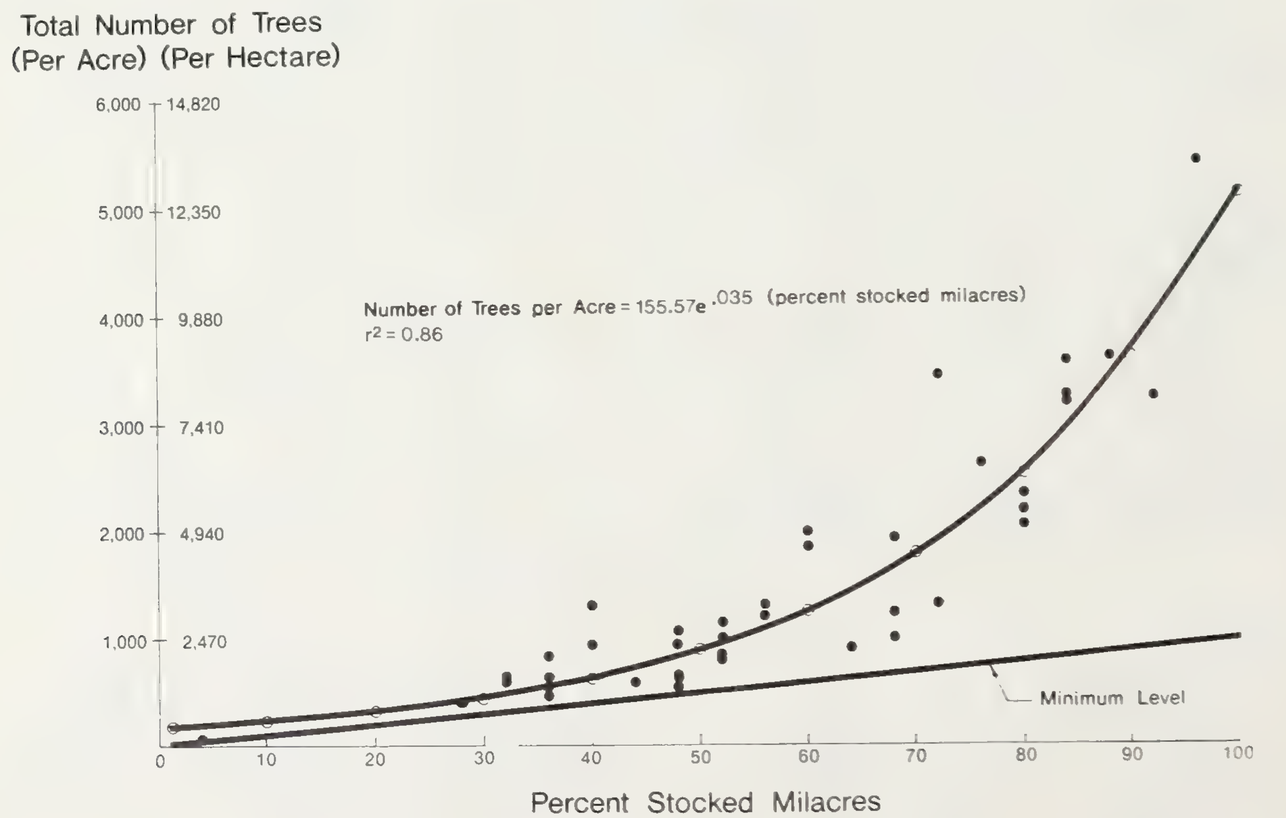


Figure 2.--Relationship of 1-milacre-stocking percent to total number of trees per acre for all 43 plots in the eastern Cascades. The minimum level curve indicates the expected relationship if there were no more than one tree per stocked milacre.

relationship if there were only one tree on each stocked milacre.

In addition to average stocking or density of reproduction, plots were grouped into several stocking classes to provide insight into the regeneration status on the clearcuts. For this purpose, plots in both plant communities were grouped according to the number and percentage which attained specific levels of stocking or density (table 3). Depending on one's definition of adequate stocking, the proportion of clearcut areas successfully regenerated can be determined. For example, if 40-percent stocking of milacre quadrats is considered satisfactory, then 50 percent of the clearcuts in mountain hemlock meet this standard compared with 73 percent of clearcuts in mixed conifer.

While surveying plots in mountain hemlock community, it was obvious that the 10 plots that had not been planted had much more reproduction than 18 plots that had been planted. Summarizing the data for planted and unplanted plots revealed that not only was there about five times as much advance reproduction on the unplanted plots as on the planted plots but numbers and stocking of 3-year and older subsequent reproduction were also much greater on the unplanted plots (table 4). The reason for these sizeable differences in stocking became apparent after looking at the same plots in terms of slash versus no slash treatment which corresponded closely to the planted versus unplanted grouping except for four plots that had been planted but where slash was left untreated. Much more advance reproduction was found on the unplanted plots because it was not destroyed during slash disposal. The reason for better stocking of subsequent regeneration on the untreated plots is not as apparent but may be due, in part, to the beneficial effects of the slash in modifying the microclimate at the soil surface.

Table 3--Proportion of clearcut plots in east-side Oregon Cascades stocked at various levels with 3-year and older regeneration (advance and subsequent)[1/]

Stocking percent			Number trees/acre		
Minimum stocking	Samples	Proportion of total	Minimum stocking	Samples	Proportion of total
Percent	Number		No./acre	Number	
		Mt. hemlock/grouse huckleberry--28 plots			
20	24	0.86	200	26	0.93
40	14	.50	400	20	.71
60	9	.32	700	14	.50
80	5	.18	1000	11	.39
			2000	5	.18
		Mixed conifer/snowbrush-chinkapin--15 plots			
20	15	1.00	200	15	1.00
40	11	.73	400	13	.87
60	4	.27	700	8	.53
80	0	.00	1000	4	.27
			2000	0	.00

1/ Based on 1-milacre quadrats.

Table 4--Average stocking percentage and number per acre, with standard errors, of planted, unplanted slash treated, and untreated clearcuts in the Cascade mountain hemlock/grouse huckleberry community by class of reproduction (based on 1-milacre subplots)

Class of reproduction	Planted		Unplanted		Slash treated		Slash not treated	
	Stocking percent	Number per acre	Stocking percent	Number per acre	Stocking percent	Number per acre	Stocking percent	Number per acre
Advance	9.1±2.9	224±81	34.4±8.3	1020±337	6.9±2.6	157±73	32.9±5.3	860±256
Subsequent 3 years and older	18.2±3.2	353±91	44.0±8.9	1024±243	18.0±3.9	349±112	36.9±7.2	837±193
Planted	14.0±2.8	149±29	--	--	14.3±3.5	125±22	13.3±5.1	77±11
All classes except 1st and 2d years	36.4±4.5	726±148	61.6±10.2	2044±488	33.4±5.7	631±172	57.4±7.3	1774±371

Advance reproduction played an important regeneration role on the mountain hemlock clearcuts not only because of amounts present but also because of its size and growth potential. No systematic height growth measurements were taken in this study, but occasional observations of annual height growth of 1 to 2 feet were not uncommon on vigorous full-crowned true firs and hemlocks. Of course, not all advance reproduction is sufficiently vigorous to respond to release quickly; but if adequate numbers of healthy trees remain after logging, uncertainties of establishing a new stand by planting or natural regeneration can be avoided.

Species Composition of Regeneration

The regeneration in both plant communities was composed of a mixture of species. In the mountain hemlock type, more subplots were stocked with Shasta red fir (advance and subsequent) than any other species (table 5). Mountain hemlock was also a major species; stocking of advance and subsequent regeneration was about equal. The other two major species were white pine and lodgepole pine, primarily of older subsequent origin. If all origins are combined, average stocking of the four major species is ranked as follows: Shasta red fir, 25.4 percent; lodgepole pine, 17.3 percent; mountain hemlock, 13.9 percent; western white pine, 9.1 percent. Most of the reproduction on these clearcuts was of natural origin. Lodgepole pine was the primary species planted and accounted for 64 percent of the lodgepole pine regeneration on the nine plots where it was planted but for only 17 percent of the total number of trees on these plots. Some plots were also planted with true firs and western white pine, but they contributed little to the total stocking.

Species composition in the mixed conifer/snowbrush-chinkapin community differed considerably from the mountain hemlock. Grand fir and ponderosa pine were the two major species present--on the average occurring on 25.3 and 33.6 percent of the subplots, respectively (table 5). Lodgepole pine was the third most common species on the mixed conifer clearcuts and minor amounts of Shasta red fir, Douglas-fir, and western white pine were also found. Grand fir stocking of young and older postharvest origin was about equal while 94 percent of the ponderosa pine stocking originated from planting.

During the survey, I observed that ponderosa pine was planted not only on clearcuts in the mixed conifer forest but also on some of

Table 5--Average stocking percentage, with standard errors, of advance and subsequent regeneration on clearcuts in the east-side Oregon Cascades by species and plant community (based on 1-milacre subplots)

Species	Mt. hemlock/grouse huckleberry: Advance	Subsequent[1/]: 3 years and older	Subsequent[1/]: 1 and 2 years old	All classes	Mixed conifer/snowbrush chinkapin: Advance	Subsequent[1/]: 3 years and older	Subsequent[1/]: 1 and 2 years old	All classes
	Stocking percent (± standard error)							
Grand fir	0.7±0.4	1.3±0.6	0.6±0.3	1.6±0.6	1.9±0.8	12.0±3.3	16.3±3.3	25.3±4.1
Shasta red fir	9.7±3.2	13.0±2.7	8.1±2.9	25.4±4.9	3.1±1.4	2.1±1.2	2.1±0.9	5.6±2.1
Pacific silver fir	0.1±0.1	1.0±0.6	3.4±2.6	4.4±2.7	0.0± --	0.0± --	0.0± --	0.0± --
Douglas-fir	0.0± --	0.3±0.2	0.3±0.3	0.4±0.3	0.3±0.3	2.9±1.7	1.3±0.6	4.0±1.8
Mountain hemlock	6.6±1.6	6.0±1.4	2.1±0.8	13.9±2.5	0.0± --	0.0± --	0.0± --	0.0± --
Engelmann spruce	0.1±0.1	0.1±0.1	0.0± --	0.3±0.3	0.0± --	0.8±0.6	0.5±0.4	1.1±0.8
Western white pine	2.6±0.9	6.1±1.9	0.7±0.3	9.1±2.3	0.3±0.3	2.4±0.9	1.5±0.9	3.5±1.3
Ponderosa pine	0.3±0.3	4.1±1.8	0.0± --	3.4±1.7	0.0± --	31.2±5.5	0.3±0.3	33.6±5.0
Lodgepole pine	3.6±1.5	12.7±2.6	3.7±1.4	17.3±3.2	0.0± --	4.8±2.4	6.4±3.9	9.3±4.9

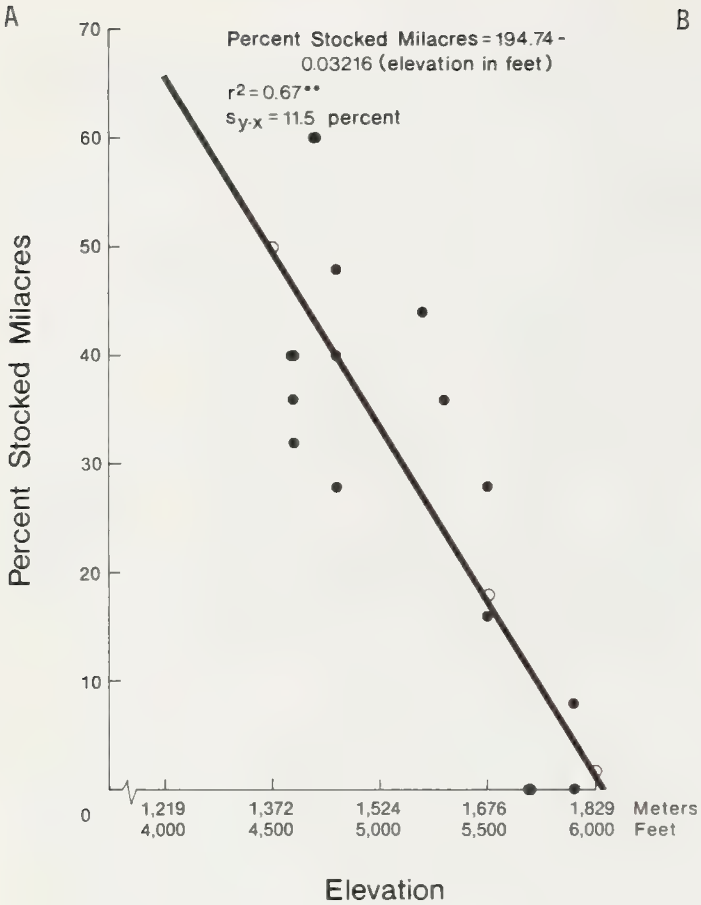
[1/]Includes natural and planted regeneration.

the higher elevation clearcuts in the mountain hemlock. There appeared to be a noticeable decrease in ponderosa stocking with increasing elevation although all plots had been planted at an 8- x 8-foot spacing (681 trees per acre). Analysis of the data showed there was a highly significant negative linear relationship between planted ponderosa pine stocking percent or number of trees and elevation (fig. 3). In addition to the increase in mortality associated with greater elevation, there was also a noticeable increase in the amount of snow damage (stem deformation and breakage).

Dominant Species

Measurements of stocking and density alone do not give a complete picture of the regeneration pattern. A species may predominate in terms of numbers and yet be less important in the immediate future of the developing stand than another species that is less abundant but larger or more vigorous. This situation occurred in this study. In the mountain hemlock clearcuts, planted lodgepole pine was a minor regeneration component in terms of numbers but was classified as the dominant tree on 18.7 percent of stocked subplots--the largest percentage of any species-origin combination (table 6). It is obvious that reproduction on the mountain hemlock clearcuts is composed of a number of dominant species (Shasta red fir, mountain hemlock, white pine, and lodgepole pine) and is about equally divided among advance, natural subsequent, and planted origin.

In contrast to the mixed species and origin classes of reproduction in the mountain hemlock clearcuts, regeneration in the mixed conifer clearcuts is dominated by one species--planted ponderosa pine. Planted trees were dominant on 82 percent of the stocked subplots; ponderosa pine on 76 percent and Douglas-fir on 6 percent (table 6). True fir regeneration was dominant on only 10 percent of the stocked subplots even though present in considerably greater numbers than the planted ponderosa pine. Prompt reforestation of these clearcuts with planted ponderosa pine is clearly superior to waiting for natural regeneration to do the job. Many of the planted pine are now 3- to 5-inch d.b.h., 10 to 15 feet tall, and growing 1 to 2 feet annually in height. On the other hand, most of the natural fir regeneration was less than 4 feet tall and growing in the shade of the pines.



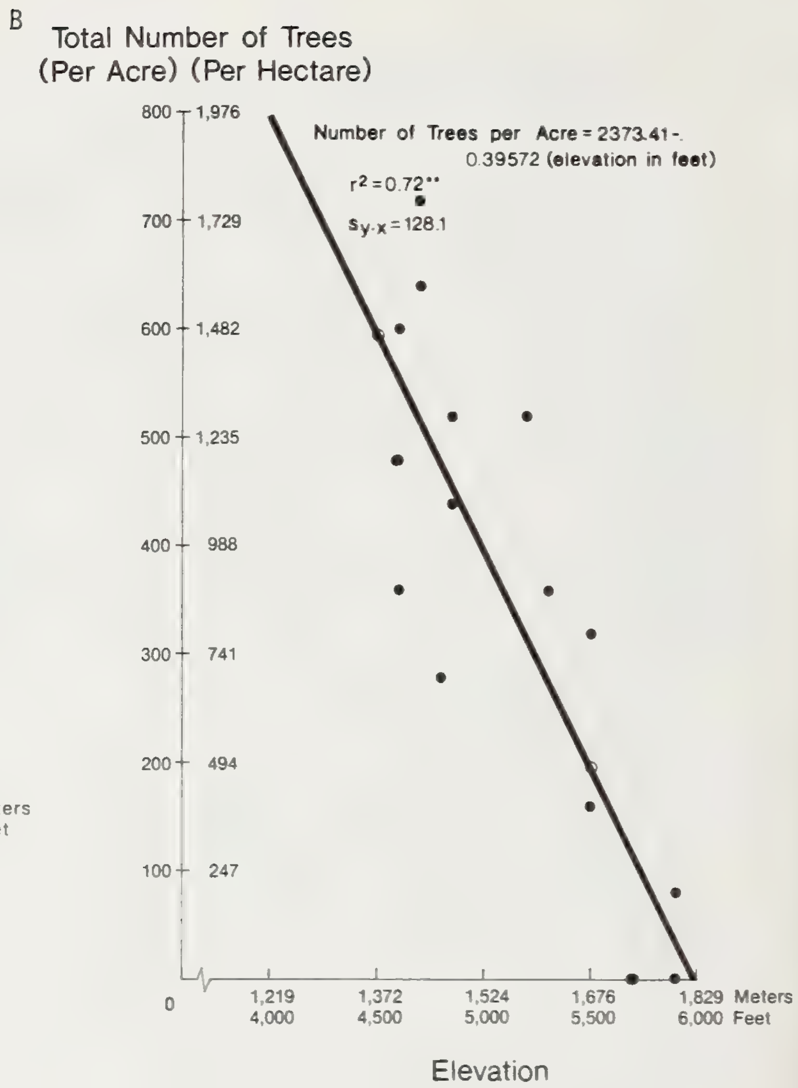


Figure 3.--In the eastern Cascades, establishment of planted ponderosa pine decreased as elevation increased: A--In stocked milacres; B--in number of trees per acre.

Table 6--Species and origin of dominant trees on east-side Oregon Cascade clearcuts by plant community[1/]

Origin	Species								
	Grand fir	Shasta red fir	Pacific silver fir	Douglas-fir	Mt. hemlock	Western white pine	Ponderosa pine	Lodgepole pine	Total
	Mt. hemlock/grouse huckleberry								
	(Percent of stocked subplots)								
Advance	0.2	13.3	0.5	--	10.2	5.1	--	7.6	36.9
Natural subsequent	0.5	9.5	3.7	0.2	3.4	5.5	0.2	8.8	31.8
Planted	--	0.2	1.1	--	--	1.9	9.4	18.7	31.3
Total	0.7	23.0	5.3	0.2	13.6	12.5	9.6	35.1	100.0
	Mixed conifer/snowbrush-chinkapin								
	(Percent of stocked subplots)								
Advance	1.4	0.6	--	--	--	--	--	--	2.0
Natural subsequent	6.9	0.9	--	1.2	--	0.9	0.6	5.5	16.0
Planted	--	--	--	6.2	--	--	75.8	--	82.0
Total	8.3	1.5	--	7.4	--	0.9	76.4	5.5	100.0

[1/] Based on 4-milacre subplots. One- and 2-year seedlings included.

Relation of Present Stocking to Environmental Factors

The influence of observed environmental factors on regeneration and their relative importance in describing present stocking were determined by stepwise regression analyses. The results of these analyses are presented in table 7, which shows the positive or negative relationship to stocking and the order in which variables appeared in the equations.

In the mountain hemlock clearcuts, both grass and forbs have a consistent negative relationship to stocking of all species or classes; in other words, the more grass or forbs present the less regeneration. Except for lodgepole pine and white pine, grass was always one of the first three variables in these equations (table 7). As expected, aspect always appeared as a positive term indicating regeneration generally was greater on more northerly aspects. An increase in elevation resulted in less regeneration, but this variable usually entered as one of the last factors. In most equations, burning (pile and burn) had a negative effect on establishment of regeneration. This agrees with the work of Vogl and Ryder (1969) who reported 80-percent-less reproduction on severe burns than on unburned areas in the mixed conifer type in Montana.

Effect of most factors is logical and has reasonable biological explanations. An exception is the effect of distance from timber. In all equations where it appeared, it was a positive term thus indicating greater stocking as distance from the clearcut edge increased, contrary to the usual expectation of less regeneration. An examination of its single variable relationship to stocking, however, showed that within the 8-chain distance from the timber edge that was sampled in this survey, there was essentially no difference in stocking of natural regeneration (r=.001). Therefore, this variable could appear with a positive or negative sign depending on the combination of variables involved in the regression. Lack of correlation between distance from clearcut edge and stocking within limited distances from edge of the stand has also been reported by Franklin (1963) in western Cascade clearcuts.

The effect of these variables on stocking depends upon the species and origin of reproduction and the plant community. It is also evident that in some cases where there is essentially no relationship between stocking and a single variable, the influence of this variable in a specific regression equation may be opposite of its effect in the single variable correlation. If we keep these inconsistencies in mind, the general effect of these variables on stocking in the mountain hemlock and mixed conifer communities can be summarized by listing those associated with increased stocking, decreased stocking, or having no strong relationship to stocking as follows:

MOUNTAIN HEMLOCK COMMUNITY

Increased stocking	*Decreased stocking*	*Little relationship*
More northerly aspects	More grass	Age of clearcut
More litter and slash	Increased severity of burn	Elevation
	More forbs	Slope
		Mineral soil
		Woody vegetation
		Distance to timber

Table 7--Positive and negative correlations of variables and order in which they appeared in regression equations describing stocking of regeneration in the Cascades by plant community

Species or origin class	Variable[1/]														
	Age	Elevation	Aspect	Slope	Mineral soil	Litter	Slash	Litter and slash	Burn (pile and burn)	Forbs	Woody	Grass	Distance from timber	R^2	Standard error of stocking percent
Mountain hemlock/grouse huckleberry															
All regeneration	[2/]-6	-5	+3	--	--	--	--	--	-2	-4	--	-1	--	0.75	14.6
All natural regeneration	--	-5	+4	--	--	--	--	--	-2	-3	--	-1	--	.76	15.8
3+ years old	+2	-5	--	--	--	--	--	+1	--	--	--	-3	+4	.72	13.5
1 & 2 years old	-2	--	+5	--	--	--	--	-7	-6	-4	--	-1	+3	.80	10.6
All true fir	--	--	+5	--	--	--	--	+3	-2	--	-4	-1	--	.67	16.1
Subsequent true fir	+5	--	--	--	--	--	--	+1	--	--	-4	-3	+2	.59	10.3
All white pine	+2	--	+1	--	-4	--	--	--	--	-6	-5	-3	--	.65	8.3
Subsequent white pine	+2	--	+1	--	--	--	--	+3	--	--	-4	--	--	.43	8.3
All lodgepole pine	--	--	+2	-3	--	--	--	--	-1	-4	--	--	--	.44	13.6
Subsequent lodgepole pine	+1	--	+4	--	--	-3	--	--	-2	-5	--	--	--	.38	11.5
All Mt. hemlock	--	--	--	--	-4	--	--	--	--	-3	--	-2	+1	.55	9.5
Subsequent Mt. hemlock	--	--	--	-2	--	--	--	--	--	-5	+4	-3	+1	.57	5.4
Mixed conifer/snowbrush-chinkapin															
All regeneration	--	--	--	--	--	--	--	-4	-2	+5	-1	-3	--	.76	7.1
All natural regeneration	--	+4	--	--	--	-1	-5	--	-2	--	--	-3	+6	.86	10.1
3+ years old	--	+3	--	+5	+6	--	--	--	-1	--	--	-2	+4	.88	7.6
1 & 2 years old	+7	--	--	-4	--	-1	--	-3	-2	+5	+6	--	--	.86	9.6
All true fir	-3	--	-5	--	--	--	--	--	-1	--	--	-2	+4	.80	8.1
Subsequent true fir	--	--	--	+5	+6	--	+2	--	-1	--	--	-3	+4	.82	7.1

[1/]Only those variables which accounted for the major portion of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 4 percent.

[2/]Numbers indicate the order in which variables entered the regression equation.

MIXED CONIFER COMMUNITY

Increased stocking	*Decreased stocking*	*Little relationship*
None	More grass	Age of clearcut
	Increased severity of burn	Elevation
	More litter	Slope
		Mineral soil
		Litter and slash
		Distance to timber
		Aspect
		Forbs
		Slash
		Woody vegetation

Prediction Equations

Reliable equations to predict stocking after clearcutting would be useful. The regression equations summarized in the preceeding section include variables such as grass, forbs, and woody vegetation which change with time similar to the change in stocking and therefore can not be used for predictive purposes. To derive prediction equations, I used only those variables that remain independent and can be measured before or directly after harvest. Variables used were age of clearcut, elevation, aspect, slope, slash, degree of burn, and distance to timber. Strictly speaking, amount of slash and degree of burn do not remain completely unchanged over time but within the time span this study covers they changed very little.

Accurate prediction of regeneration using the six equations developed for the mountain hemlock clearcuts appears unlikely because of the large amount of unexplained variation present. The equation predicting stocking of all 1- and 2-year-old seedlings accounted for the most variation (61 percent) while the white pine and lodgepole pine equations accounted for the least and were not significant (table 8). As expected, aspect always appears as a positive term indicating greater stocking on northerly aspects and burn generally appears as a negative term similar to results of the previous section of this paper. The equation for subsequent true fir in the mixed conifer clearcuts (table 9) was the one accounting for the largest amount of variation (78 percent) in stocking percent.

Although the predictive accuracy of these equations is less than desired, it is probably as good as can be expected considering the variables involved and complex distribution pattern of natural regeneration. Unexplained variation exists for several reasons. In a survey study, no estimate of the amount of seedfall on the clearcuts is obtainable. In addition, factors measured (aspect, slope, etc.) are secondary variables. These variables influence the five primary variables (light, temperature, moisture, chemical, and physical factors) to which seedlings respond directly. Finally, it should be mentioned that, ideally, equations such as these should be checked on an independent set of data not used in their derivation. Therefore, I want to emphasize that in no way should these equations be considered as precise predictors of expected regeneration after clearcutting but only as crude estimates of possible stocking.

BLUE MOUNTAINS

Regeneration Stocking and Density

Clearcuts in the grand fir/big huckleberry community in the Blue Mountains had adequate regeneration. Total stocking averaged 51 percent on milacre subplots with a range of

Table 8--Prediction equations for stocking of regeneration on clearcuts in the Oregon Cascade mountain hemlock/grouse huckleberry community by species and class of reproduction

Dependent variable	Equation[1/]	Percent of variation explained R^2	Standard error estimate (percent) sy.x
All natural subsequent Stocking percent	= 34.08 + 4.28 (aspect) - 44.90 (burn) - 2.00 (age) - 4.29 (slope)	0.55	18.4
1- & 2-year-old Stocking percent	= -44.84 - 2.86 (age) + 2.83 (aspect) - 18.69 (burn) - 5.49 (slope) + 0.01 (elev.)	.61	14.5
Subsequent true fir Stocking percent	= 122.15 - 29.77 (burn) - 0.02 (elev.) + 4.21 (slope) + 0.82 (aspect)	.43	11.9
Subsequent white pine Stocking percent	= 30.69 + 0.93 (aspect) + 0.71 (age) - 0.01 (elev.) - 2.41 (slash)	.30[NS]	9.2
Subsequent lodgepole Stocking percent	= 0.06 + 0.83 (age) - 16.39 (burn) - 3.03 (slope) + 0.78 (aspect)	.32[NS]	11.8
Subsequent Mt. hemlock Stocking percent	= -8.31 + 0.90 (aspect) + 2.23 (distance) - 1.62 (slope)	.40	6.1

[1/] Variables are arranged in the order they entered the regression. Only variables which accounted for major portions of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 4 percent.

Table 9--Prediction equations for stocking of regeneration on clearcuts in the Oregon Cascade mixed conifer/snowbrush-chinkapin community by species and class of reproduction

Dependent variable	Equation[1/]	Percent of variation explained R^2	Standard error estimate (percent) sy.x
All natural subsequent Stocking percent	= 112.96 + 7.24 (slash) + 4.22 (distance) - 133.99 (burn) - 5.45 (age)	.57[NS]	16.3
1- & 2-year-old Stocking percent	= 59.70 - 4.87 (age) - 117.19 (burn) - 8.22 (slope) + 0.01 (elev.)	.62	13.2
Subsequent true fir Stocking percent	= 21.59 = 78.90 (burn) + 3.11 (slash) + 0.59 (aspect) + 5.13 (distance) + 6.24 (slope) - 1.78 (age)	.78	7.8

[1/] Variables are arranged in order they entered the regression. Only variables which accounted for major portions of variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 4 percent.

12 to 96 percent (table 10), about the same as average stocking in the Cascade region. On a 4-milacre basis, total stocking in Blue Mountain clearcuts averaged 81 percent.

Advance reproduction played a relatively minor role in these clearcuts, comprising the smallest regeneration component in both stocking and trees per acre (table 10) because of losses due to logging and slash treatment (mostly broadcast burning). The largest single component was 3-year and older natural regeneration averaging 1,135 stems per acre and found on 34 percent of the subplots. While planted trees averaged only 240 per acre, they occurred on 21 percent of the milacres because of their good distribution.

As in the Cascades, the presence of 1- and 2-year-old seedlings raised density levels but did not change stocking to any large extent. Their presence increased stocking on 40 percent of the plots, but on only 2 of the 50 plots was the gain 12 percent or greater. On one of the two plots, stocking increased by 12 percent and on the other by 16 percent.

The same exponential relationship between density of regeneration and stocked milacres was found on the Blue Mountain plots as well as the Cascades (fig. 4).

Distribution of plots into various stocking classes showed that 66 percent of the plots were at least 40 percent stocked and 56 percent had at least 700 trees per acre 3 years and older (table 11). On some plots, overstocking rather than understocking was the problem. For example, considering total number of trees of all species, seven plots had more than 4,000 trees per acre;

Table 10--Average stocking percentage and number per acre, with standard errors, of all species on clearcuts in the eastern Oregon Blue Mountains, grand fir/big huckleberry plant community by class of reproduction (based on 1-milacre quadrats)

Class of reproduction	No. plots	Mean±S.E.	Range
		Stocking percent	
Advance	50	5.8±1.3	0-48
Subsequent			
1 & 2 year	50	13.0±2.5	0-64
3+ year	50	34.1±3.5	0-88
Planted	50	21.2±1.8	0-48
All classes except 1 & 2 year	50	48.7±2.8	12-88
All classes	50	51.4±3.1	12-96
		Number per acre	
Advance	50	82.0±26	0-920
Subsequent			
1 & 2 year	50	513±179	0-6040
3+ year	50	1135±225	0-8560
Planted	50	240±25	0-840
All classes except 1 & 2 year	50	1457±231	120-8720
All classes	50	1970±382	120-14760

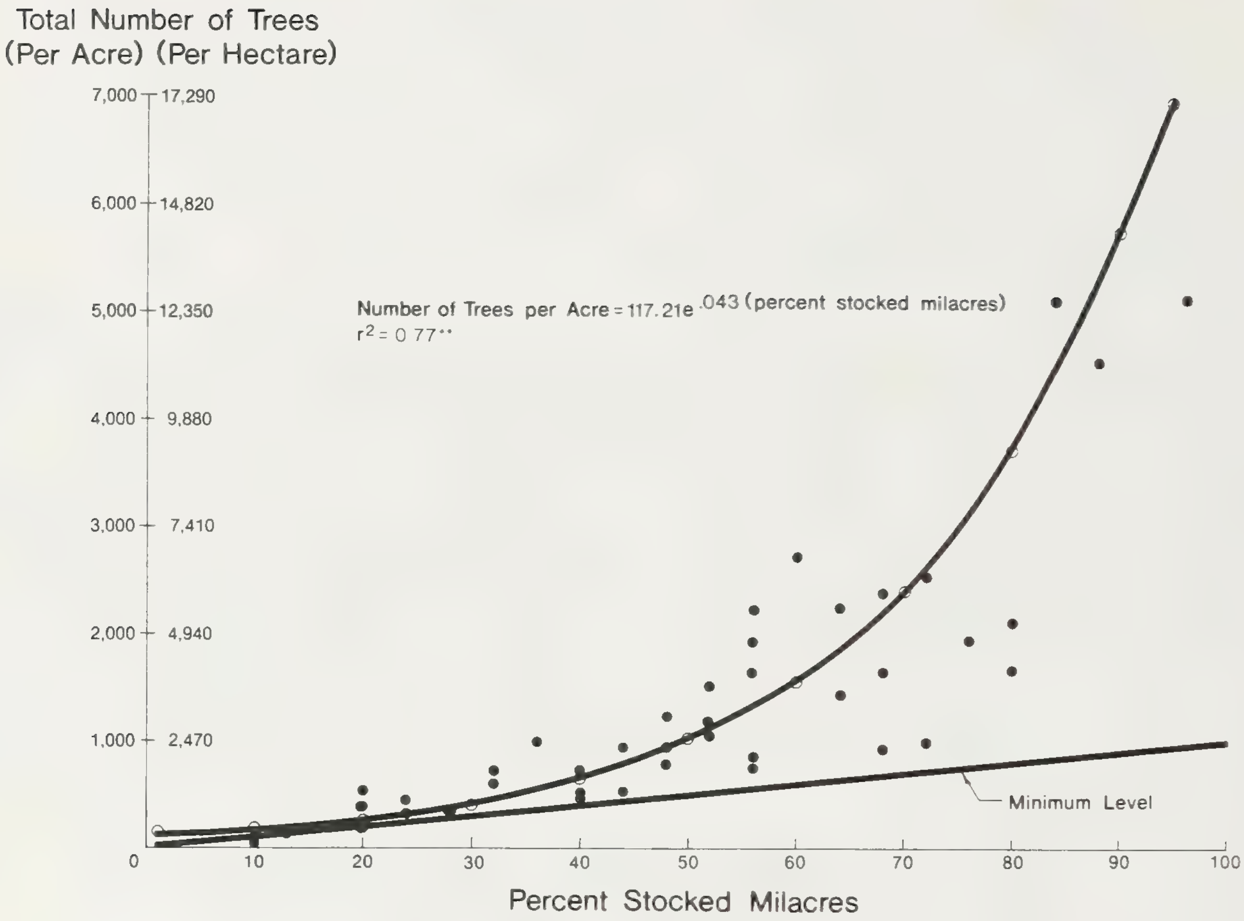


Figure 4.--Relationship of 1-milacre stocking percent to total number of trees per acre for all 50 plots in the Blue Mountains. The minimum level curve indicates the expected relationship if there were no more than one tree per stocked milacre.

Table 11--Proportion of clearcut plots in the eastern Oregon Blue Mountains stocked at various levels with 3-year and older regeneration (advance and subsequent)1/

Stocking percent			Number trees/acre		
Minimum stocking	Samples	Proportion of total	Minimum stocking	Samples	Proportion of total
Percent	Number		No./acre	Number	
20	49	0.98	200	49	0.98
40	33	.66	400	40	.80
60	19	.38	700	28	.56
80	4	.08	1,000	21	.42
			2,000	10	.20
			3,000	6	.12

1/ Based on 1-milacre quadrats. Total number of sample plots = 50.

the greatest density was 14,670 on one plot.

Species Composition of Regeneration

As expected, regeneration on these clearcuts consisted of a number of species. Grand fir and Engelmann spruce were the two most common species, occurring on 29.8 and 17.1 percent of the subplots (table 12). Ponderosa pine was the third major species and smaller amounts of Douglas-fir, lodgepole pine, and western larch were also present. For all species, the 3-year and older component made up the largest part of the regeneration.

Ponderosa pine was the predominant planted species. It was planted on 47 of the 50 plots and accounted for essentially 100 percent of ponderosa pine regeneration. All of the other species except western larch and lodgepole pine were also planted to some extent--Douglas-fir and Engelmann spruce most often. Douglas-fir was planted on 15 plots and accounted for 40 percent of all surviving Douglas-fir on these plots, but only 4 percent of all species. Spruce was planted on six plots and grand fir on nine; planted trees made up about 10 percent of each species and 5 percent of all reproduction.

In the Blue Mountains, no significant relationship was found between stocking of planted ponderosa pine and elevation. Only a slight downward trend in stocking occurred as elevation increased, but an increasing amount of snow damage was observed at elevations above 5,300 feet.

Dominant Species

All six species found on these clearcuts were dominant on at least 7 percent of the stocked subplots (table 13). Because of its wide distribution, planted ponderosa pine was the predominant species--occurring on 43 percent of the quadrats. Grand fir and lodgepole pine were dominant on 18.3 and 13.9 percent of the subplots, respectively; most of these were of natural subsequent origin.

Just as on Cascade plots, consideration of dominant tree in addition to total numbers or stocking gives a clearer picture of future stand composition. For example, even though ponderosa pine averaged only 180 per acre compared to 3 to 5 times as many fir and spruce, planted pine clearly dominanted because of its good distribution and rapid growth.

Table 12--Average stocking percentage, with standard errors, of advance and subsequent regeneration on clearcuts in the eastern Oregon Blue Mountains by species

Species	Advance	Subsequent		All classes
		3 years & older	1 & 2 years old	
	- - - - - - - - - Stocking percent±S.E. - - - - - - - -			
Grand fir	3.4±0.9	27.1±3.0	7.9±1.5	29.8±2.9
Douglas-fir	0.3±0.2	9.0±2.1	2.2±1.2	9.2±2.1
Western larch	0.5±0.2	6.8±1.3	0.5±0.3	7.1±1.3
Engelmann spruce	1.1±0.5	16.3±2.9	6.1±1.9	17.1±2.9
Ponderosa pine	0.0± --	14.9±1.9	0.3±0.2	14.9±1.9
Lodgepole pine	1.1±0.6	8.2±2.5	2.8±1.1	9.1±2.6

Table 13--Species and origin of dominant trees on eastern Oregon Blue Mountain clearcuts[1/]

Origin	Species						
	Grand fir	Douglas-fir	Western larch	Engelmann spruce	Ponderosa pine	Lodgepole pine	Total
	Percent of stocked subplots						
Advance	6.2	0.5	0.6	2.0	--	0.3	9.6
Natural subsequent	11.1	2.9	6.8	4.8	0.1	13.6	39.3
Planted	1.0	3.3	--	3.7	43.1	--	51.1
Total	18.3	6.7	7.4	10.5	43.2	13.9	100.0

[1/]Based on 4-milacre subplots. One and 2-year seedlings included.

Relation of Present Stocking to Environmental Factors

In the Blue Mountain plots, fewer variables generally accounted for most variation in stocking and there was a more consistent positive or negative correlation between species or origin classes and environmental factors (table 14). Elevation and slope were the two variables most strongly related to stocking; both in a positive manner. It is interesting that greater stocking was definitely associated with higher elevations contrary to results in Cascade clearcuts. Increased stocking at higher elevations consisted of an abundance of spruce, grand fir, and lodgepole pine natural regeneration. Aspect was again positively correlated to stocking in most regressions, and grass was generally a negative factor in regeneration occurrence. Forbs entered some equations as a positive factor, but single variable correlation showed it to be weakly related to stocking in a negative manner.

Although degree of burn did not contribute much to explained variation, it was positively correlated with stocking in contrast to negative correlation on the Cascade plots. Although no direct evidence is available from this study, it is interesting to speculate that perhaps this difference in effect may, in part, be due to difference in method of burning--pile and burn in the Cascades vs. broadcast burn in the Blue Mountains.

The Douglas-fir and larch equations were the only equations where mineral soil accounted for a large part of the variation in stocking (table 14). For Douglas-fir, it was the first variable entered and it showed a strong positive correlation with stocking; while for larch, a very weak positive correlation existed but it appeared in the equation as a negative term. It is widely recognized that mineral soil is a desirable seed bed. Surface temperatures are lower on mineral soil than on heavy litter and duff layers (Gordon 1970), and mineral soil is a more stable water source. The advantages of a mineral soil seed bed have been clearly shown in studies where such a treatment was compared with other seed beds and other factors were held more or less constant. Seedlings, however, are able to become established in moderate layers (1/2- to 1-inch) of organic matter. In fact, Ryker (1975) reported more natural regeneration of Douglas-fir on litter-covered seed beds than on mineral soil in the Intermountain region. In my study, where many variables are related in a complex pattern, mineral soil was not a major factor in describing the occurrence of regeneration.

Table 14--Positive and negative correlations of variables appearing in regression equations describing stocking of regeneration in the Blue Mountains

Species or origin class	Variable[1/]													
	Age	Eleva-tion	Aspect	Slope	Mineral soil	Litter	Slash	Litter and slash	Burn (broad-cast)	Forbs	Woody	Grass	Distance from timber	R^2	Standard error in stocking percent
All regen-eration	--	[2/] +2	+5	+1	--	--	+6	--	+4	--	--	-3	--	0.55	15.7
All natural regeneration	--	+2	+4	+1	--	--	--	--	--	+3	--	--	--	.47	19.4
3 years & older	--	+2	+3	+1	--	--	--	--	--	+4	--	--	--	.49	18.3
1 & 2 years	--	+1	--	+3	--	--	--	--	--	--	--	-2	--	.51	12.8
All grand fir	--	+4	+3	+1	--	--	--	--	--	--	--	-2	--	.40	16.8
Subsequent grand fir	--	+4	+2	+1	--	--	--	--	--	--	--	-3	--	.39	17.1
1 & 2 year grand fir	-4	+1	--	+2	--	--	--	--	--	--	--	-3	--	.40	8.8
All spruce	--	+1	+2	--	--	--	--	--	--	--	-4	-3	--	.43	16.0
Subsequent spruce	--	+1	+2	--	--	--	--	--	+4	--	--	-3	--	.45	15.9
All larch	--	+2	+4	+1	-3	--	--	--	--	--	--	--	--	.33	7.8
Subsequent larch	--	+2	+4	+1	-3	--	--	--	--	--	--	--	--	.35	7.8
All Douglas-fir	--	+5	+3	+2	+1	--	--	--	--	+4	--	--	--	.60	9.7
Subsequent Douglas-fir	--	+4	+3	+2	+1	--	--	--	--	+5	--	--	--	.61	9.5

1/ Only those variables which accounted for the major portion of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

2/ Numbers indicate the order in which variables entered the regression equation.

In the Blue Mountain region, the environmental variables are generally related to stocking as follows:

Increased stocking	Decreased stocking	Little relationship
Higher elevation	More grass	Age of clearcut
More northerly aspect		Mineral soil
Greater slope		Litter and slash
Increased severity of burn		Forbs
		Woody vegetation

Animal damage of any kind was light on both Blue Mountain and Cascade plots. Gopher activity was observed on only 2 percent of the subplots in Blue Mountain clearcuts and on 1 percent in the Cascades. Occasional ponderosa pine saplings were damaged by porcupines.

Prediction Equations

Less than one-half of the variation in stocking was explained by prediction equations developed for Blue Mountain plots; ranging from 31 percent for the subsequent larch equation to 49 percent for all 1- and 2-year-old seedlings (table 15). Except for the burning variable in the first equation, only aspect, slope, and elevation strongly correlate with stocking. As expected, these three variables appear in all equations as a positive term just as they do in equations describing present stocking.

Conclusions and Recommendations

Survey results provide a broad overview of regeneration status on clearcuts in upper slope mixed conifer forests of the eastern Cascades and Blue Mountains. Such information is useful in evaluating harvesting methods, discovering differences in

Table 15--Prediction equations for stocking of regeneration on clearcuts in the Oregon Blue Mountains by species and class of reproduction

Dependent variable	Equation[1/]	Percent of variation explained R^2	Standard error estimate (percent) sy.x
All natural subsequent Stocking percent	= -43.27 + 12.83 (slope) + 0.01 (elev.) + 1.24 (aspect) + 14.05 (burn)	0.47	20.1
1- & 2-year-old Stocking percent	= -72.86 + 0.02 (elev.) + 3.86 (slope) + 0.64 (aspect)	.49	13.0
Subsequent grand fir	= 6.68 + 10.34 (slope) + 1.13 (aspect)	.34	17.5
Subsequent Douglas-fir	= -50.92 + 0.01 (elev.) + 4.32 (slope) + 0.87 (aspect)	.46	11.0
Subsequent larch	= -14.10 + 3.93 (slope) + 0.003 (elev.) + 0.34 (aspect)	.31	8.0
Subsequent spruce	= -72.54 + 0.02 (elev.) + 1.43 (aspect)	.40	16.2

[1/] Variables are arranged in the equation in the order in which they entered the regression. Only those variables which accounted for the major portion of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

regeneration between plant communities, and identifying problem areas. I want to emphasize, however, that these results are broad averages and do not indicate the precise regeneration picture on any specific National Forest or Ranger District within the study area. Also, I would like to point out that the purpose of the survey was to compare and evaluate regeneration that has developed on mixed conifer clearcuts and is *not* to be considered as a recommendation for use of this silvicultural system to exclusion of others.

Generally, reforestation on these clearcuts has been quite satisfactory. The combination of advance, natural subsequent, and planted reproduction has resulted in adequate stocking on most of the clearcuts surveyed, and in overstocked conditions on some. It should be noted here that generally the forester's attention is focused on problems of establishing regeneration and too often the problem of an overabundance of trees is neglected. The early implementation of stocking level control is especially important for seral species such as larch and lodgepole pine where crowns quickly decrease in size and growth is lost if thinning is delayed.

Advance reproduction played a significant role in the Cascade mountain hemlock clearcuts where slash was not treated. Many mature stands in this plant community have a well-stocked understory of true fir and mountain hemlock saplings and poles. Even though suppressed for many years, vigorous, fully crowned understory trees will respond to release (Seidel 1977). It was evident that advance reproduction *can* be saved if felling and skidding operations are planned to minimize damage to the understory. Barrett et al. (1976) have shown it is possible to save sufficient numbers of ponderosa pine understory during logging and slash disposal to form the new stand by marking understory crop trees before harvest and using unconventional slash disposal methods. Such techniques should be applicable to mixed conifer stands where topography permits.

Natural regeneration established after clearcutting generally resulted in considerable numbers of seedlings, although in many cases distribution was patchy and seedlings were overtopped by brush. Despite the presence of many seedlings of natural origin on these clearcuts, relying on natural regeneration as the primary method of regenerating mixed conifer clearcuts is not recommended when intensive forest management is practiced. There is no assurance that natural regeneration will occur within any specific time period because of many factors such as seed supply and microclimate which are beyond the forester's control. If significant amounts of grass invade the clearcut before a good seed year occurs, probability of seedling establishment will decrease. In this study, woody vegetation (snowbrush, manzanita) was not a negative factor in seedling establishment but severely reduced growth of young trees.

In clearcuts where no advance reproduction exists or where it has been destroyed in the logging and slash disposal operations, planting is the obvious choice for stand establishment rather than relying on natural regeneration. Planting promptly restores the area to timber production before it is taken over by grass or woody vegetation, and enables the land manager to choose spacing to meet his objectives. At elevations below about 5,300 feet, ponderosa pine is clearly the preferred species to plant because its good survival and rapid growth rate result in full site utilization within a short period. In such plantations, ponderosa pine will be dominant for many years but in the long run a typical mixed conifer stand will result because of natural regeneration of other species and the trend of succession to more shade tolerant species. In higher elevation clearcuts, lodgepole pine is a desirable species to plant because of its greater resistance to snow damage. In the Blue Mountains, western larch appears to be a promising species to plant in higher elevation clearcuts, although surprisingly little larch has been planted in this area.

Establishment of mixed species plantations also reduces the chance of losing an entire plantation to insect or disease attacks. Of course, establishment of successful plantations is not a simple matter. It involves a complex series of operations including correct seed source, production of vigorous nursery stock, proper lifting, handling, and storage of stock, careful planting procedures, and animal damage control. It is beyond the scope of this paper to discuss details of these many and varied operations. All regeneration foresters, however, would be well advised to read guidelines for plantation establishment prepared by Cleary et al. (1978).

In clearcuts where advance reproduction provides almost adequate stocking, natural regeneration could augment this stocking by filling in holes created by skid trails and slash disposal operations. If natural regeneration is used to supplement advance reproduction, slash disposal should be minimized. This not only prevents unnecessary destruction of the advance reproduction but some slash on the ground creates a more favorable environment for seedling establishment by moderating temperature extremes. In conclusion, because of the uncertainties associated with obtaining natural regeneration, it seems best suited as a supplemental rather than a primary method of regenerating mixed conifer clearcuts.

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Appendix

I. Independent (X) variables used in regression analyses.

1--Age of clearcut. The number of years since the area was harvested.

2--Elevation. The average elevation of the plot to the nearest 10 feet as measured with an altimeter.

3--Aspect. One of eight compass points measured on each subplot. Aspect was coded using the method proposed by Day and Monk (1974), in which the following values were assigned to compass directions: N - 14; NE - 15; E - 11; SE - 7; S - 3; SW - 2; W - 6; NW - 10. Average coded value of the 25 subplots was used in analyses.

4--Slope. Percentage slope of each subplot was measured with clinometer and coded as follows: 0-9%......0; 10-19%......1; 20-29%......2; 30-39%......3; etc. Average coded value of subplots used.

5--Mineral soil. The percentage of each subplot containing mineral soil was estimated, coded in the same way as slope values, and averaged.

6--Litter. The percentage of each subplot covered with litter was estimated, coded in the same way as slope values, and averaged.

7--Slash. The percentage of each subplot covered with slash was estimated, coded in the same way as slope values, and averaged.

8--Litter and slash. The percentage of each subplot covered with litter and slash was estimated, coded in the same way as slope values, and averaged.

9--Degree of burn. Estimated on each subplot and coded as None......0; Light......1; Medium......2; Heavy......3. Average coded value used in analyses. Degree of burn definitions are: None--no visible effect of fire. Light--fire charred surface of forest floor but did not remove all of litter layer. Medium--fire removed all of litter layer and some of the duff. Heavy--fire removed all litter and duff and imparted a coloration to the mineral soil.

10--Forbs. The percentage of each subplot covered with forbs was estimated, coded in the same way as slope values, and averaged.

11--Woody perennials. The percentage of each subplot covered with woody perennials was estimated, coded in the same way as slope values, and averaged.

12--Grasses and sedges. The percentage of each subplot covered with grasses and/or sedges was estimated, coded in the same way as slope values, and averaged.

13--Distance to timber edge. The distance from each subplot to the nearest timber edge was estimated to the nearest chain and averaged.

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Seidel, K. W.
1979. Regeneration in mixed conifer clearcuts in the Cascade Range and Blue Mountains of eastern Oregon. USDA For. Serv. Res. Pap. PNW-248, 24 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

A survey of clearcuts in mixed conifer forests of the Cascade Range and Blue Mountains of eastern Oregon showed that, on the average, clearcuts were adequately reforested with a mixture of advance, natural, and planted reproduction. Planted ponderosa pine dominated clearcuts at elevations of less than 5,300 feet; and at higher elevations in the Cascades, considerable amounts of true fir and mountain hemlock advance reproduction were present. Seedling establishment was better on more northerly aspects while increasing amounts of grass had a negative effect on stocking.

KEYWORDS: Regeneration (stand), regeneration (natural), regeneration (artificial), mixed stands, Oregon (Cascade Range), Oregon (Blue Mountains), silvicultural systems (clearcutting).

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